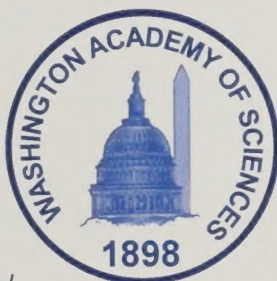


**Volume 103
Number 2
Summer 2017**

**Journal of the
WASHINGTON
ACADEMY OF SCIENCES**

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ISSN 0043-0439

Issued Quarterly at Washington DC

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Journal of the Washington Academy of Sciences (ISSN 0043-0439)

Published by the Washington Academy of Sciences

email: wajournal@washacadsci.org

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The *Journal* is the official organ of the Academy. It publishes articles on science policy, the history of science, critical reviews, original science research, proceedings of scholarly meetings of its Affiliated Societies, and other items of interest to its members. It is published quarterly. The last issue of the year contains a directory of the current membership of the Academy.

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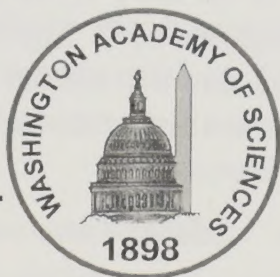
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Editor's Comments

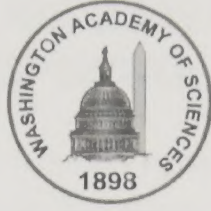
Welcome to the summer issue of the *Journal*. In this issue we include some information from the annual meeting and awards banquet held in May 2017. We installed our new Board of Directors and presented several scientific awards. Photographs of the awardees and two speeches from the outgoing and incoming President are provided at the end of this issue.

The first paper in this issue is somewhat controversial. It is a study of an old radio astronomy signal called the “Wow” signal. Observed on 15 August 1977 the signal has never had a satisfactory explanation. The author suggests a possible source for this signal. Perhaps we finally have an answer.

The second paper is the story of the first scientist in history whose name we know and writings we have. She lived in ancient Sumer (in the Fertile Crescent). It can be said that history and science began in ancient Sumer (c. 3000 BCE). She was one of the early scientists there whose work has lasted through the millennia.

Letters to the editor are encouraged. Please email (wasjournal@washacadsci.org) comments on papers, suggestions for articles, and ideas for what you would like to see in the *Journal*. We are a peer reviewed journal and need volunteer reviewers. If you would like to be on our reviewer list please send email to the above address. List your specialty.

Sethanne Howard



Journal of the Washington Academy of Sciences

Editor Sethanne Howard

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HYDROGEN LINE OBSERVATIONS OF COMETARY SPECTRA AT 1420 MHz

Antonio Paris

The Center for Planetary Science

Abstract

In 2016, the Center for Planetary Science proposed a hypothesis arguing a comet and/or its hydrogen cloud were a strong candidate for the source of the “Wow!” signal. From 27 November 2016 to 24 February 2017, the Center for Planetary Science conducted 200 observations in the radio spectrum to validate the hypothesis. The investigation discovered comet 266/P Christensen emitted a radio signal at 1420.25 MHz. All radio emissions detected were within 1° (60 arcminutes) of the known celestial coordinates of the comet as it transited the neighborhood of the “Wow!” signal. During observations of the comet, a series of experiments determined that known celestial sources at 1420 MHz (*i.e.*, pulsars and/or active galactic nuclei) were not within 15° of 266/P Christensen. In an effort to dismiss the source of the signal as emitting from 266/P Christensen, the position of the 10-meter radio telescope was moved 1° (60 arcminutes) away from comet 266/P Christensen. During this experiment, the 1420.25 MHz signal from the comet disappeared. When the radio telescope was repositioned back to 266/P Christensen, a radio signal at 1420.25 MHz re-appeared. Furthermore, to determine if comets other than 266/P Christensen emit a radio signal at 1420 MHz, we observed three comets that were selected randomly from the JPL Small Bodies database: P/2013 EW90 (Tenagra), P/2016 J1-A (PANSTARRS) and, 237P/LINEAR. During observations of these comets, we detected a radio signal at 1420 MHz. The results of this investigation, therefore, conclude that cometary spectra are detectable at 1420 MHz and, more importantly, that the 1977 “Wow” Signal was natural phenomena from a Solar System body.

Introduction

ON 15 AUGUST 1977 the Ohio State University Radio Observatory detected a strong narrowband signal in the constellation Sagittarius (Sgr) [1]. The frequency of the signal, which matched closely with the hydrogen line (1420.40575177 MHz), peaked at approximately 23:16:01 EDT [2]. On the same date and time, comet 266P/Christensen was transiting in the vicinity

where the “Wow!” Signal was detected [3]. The purpose of this investigation, therefore, was to collect and analyze radio emission spectra and determine if comet 266P/Christensen and/or any other previously unknown celestial body in the Solar System was the source of the 1977 “Wow!” Signal. This investigation, moreover, was designed to further improve our understanding of the content and origin of the “Wow!” Signal by determining if a neutral hydrogen cloud emitted from a short-period comet *could* be detected by a terrestrial radio telescope. The purpose of this investigation, conversely, was not to measure the amplitude, strength or brightness of 266/P Christensen’s hydrogen cloud. The Center for Planetary Science will conduct this part of the investigation in 2019.

10-Meter Radio Telescope and Spectrometer

For this experiment, we used a 10-meter radio telescope equipped with a spectrometer and a custom feed horn designed to collect a signal centered at 1420.25 with a total bandwidth of 6.5 MHz. The radio telescope is composed of a frontend unit which includes a low noise preamplifier and a cylindrical feed horn for 1420 MHz. The 1420 MHz signal from the LNA enters the rear panel (receiver backend) and is fed to a 1420 to 70 MHz dual conversion (internal) down converter. This converter has approximately 3 dB = 8 MHz bandwidth with the Hydrogen rest frequency at 70.0 MHz. This 3 dB = 8 MHz wide IF signal is passed through a programmable gain IF amplifier and then split between the continuum square law detector and the spectrometer third conversion mixer. The programmable gain IF amp is used to compensate for feedline losses and to place the signal in optimum range for the square law detectors [4].

The SpectraCyber software provides a control and hardware setting interface to the spectrometer. In addition, the software includes features which allowed the observer to select between spectral and continuum observations, select time coordinate systems for the data files, set the computer clock to within 500 milliseconds, and change graphical features such as background or the amplitude axis on the data plot [4]. Final modifications for the software included a rapid scan rate mode, frequency shifting from 1420.406 to a 70 MHz IF, and km/sec displayed on the X axis.

The graphs highlighted hereafter are ‘signal-averaged-intensity in volts (later converted to dB) versus frequency’ plots (in time) obtained

directly from the 10-meter radio telescope with custom acquisition times, which varied depending on the observation [8]. To convert voltage changes to decibels and determine the strength of the signal's gain, the following logarithmic formula was used:

$$dB = 20 \log \frac{V1}{V2}.$$

The data collected were then saved using the spreadsheet output format option of the SpectraCyber software and imported into Microsoft Excel as a text file. The data were then re-plotted and interpreted using the Chart Wizard feature in Microsoft Excel and converted into JPEG format.

Testing the Hypothesis

From 27 November 2016 to 24 February 2017, a series of observations in the neighborhood of the “Wow!” signal coordinates were conducted to ascertain if the alleged “Wow!” signal was natural phenomena rather than a signal from a source of extraterrestrial intelligence. These observations were made in both spectral and continuum mode (Table 1).

In continuum mode, neutral hydrogen at rest with respect to the radio telescope's acquisition time appears as a peak along the x axis while its intensity, in decibels (dB), appears along the y axis. In spectral mode, the neutral hydrogen line peaks that appear higher in frequency on the left side of the centered dashed line are due to neutral hydrogen gas receding (redshifted). Conversely, the neutral hydrogen line peaks that appear at frequencies higher on the right side of the centered dashed line are due to neutral hydrogen gas approaching (blueshifted).

Preliminary experiments from 27 November 2016 to 01 January 2017 were conducted to test, refine, and prepare for the observation of comet 266/P Christensen. The comet was then observed as it transited the area of the “Wow!” signal between 20 January 2017 and 28 January 2017. In total, 200 observations (Table 1) were completed, which comprised of:

- The Galactic Plane near the coordinates of the 1977 “Wow!” signal
- Radio Galaxy Cygnus A
- The Sun

- Comet 266/P Christensen as it transited near the coordinates of the “Wow!” signal
- Comet 266/P Christensen as it transited outside the coordinates of the “Wow!” signal.
- Clear Sky Observations near the coordinates of the “Wow!” signal, and
- Obtain a baseline of random comets to determine if they emit a radio signal at 1420 MHz:
 - Comet P/2013 EW90 (Tenagra)
 - Comet P/2016 J1-A (PANSTARRS)
 - Comet 237P/LINEAR

Date	Target	Type of Observation	Observations	1420 MHz Detected
27-Nov-16	1420 MHz Transmitter	Baseline Drift Scan to Test Feedhorn	2	Yes
12-Dec-16	Sun	Baseline Drift Scan to Test Feedhorn	4	Yes
14-Dec-16	Cygnus A	Baseline Drift Scan to Test Feedhorn	5	Yes
5-Jan-17	Sun	Baseline Drift Scan to Test Feedhorn	4	Yes
9-Jan-17	Cygnus A	Baseline Drift Scan	5	Yes
10-Jan-17	Cygnus A	Baseline Drift Scan	5	Yes
11-Jan-17	Galactic Plane	Baseline Drift Scan	5	Yes
12-Jan-17	Galactic Plane	Baseline Drift Scan	5	Yes
12-Jan-17	Galactic Plane	Baseline Drift Scan	5	Yes
13-Jan-17	Sun	Baseline Drift Scan	4	Yes
13-Jan-17	266/P	Drift Scan	4	Yes
14-Jan-17	Galactic Plane	Baseline Drift Scan	5	Yes
14-Jan-17	266/P	Drift Scan	4	Yes
19-Jan-17	Sun	Baseline Drift Scan	4	Yes
19-Jan-17	Galactic Plane	Baseline Drift Scan	5	Yes
19-Jan-17	266/P	Drift Scan	4	Yes
20-Jan-17	Sun	Baseline Drift Scan	4	Yes
20-Jan-17	Galactic Plane	Baseline Drift Scan	5	Yes
20-Jan-17	266/P (at Wow! Signal Coordinates)	Drift Scan	5	Yes
26-Jan-17	Sun	Baseline Drift Scan	4	Yes
26-Jan-17	Cygnus A	Baseline Drift Scan	5	Yes
26-Jan-17	266/P (at Wow! Signal Coordinates)	Drift Scan	4	Yes
27-Jan-17	Sun	Baseline Drift Scan	5	Yes
27-Jan-17	Cygnus A	Baseline Drift Scan	4	Yes
27-Jan-17	266/P (at Wow! Signal Coordinates)	Drift Scan	4	Yes
27-Jan-17	Clear Sky	Baseline Drift Scan	1	No
28-Jan-17	Sun	Baseline Drift Scan	2	Yes
28-Jan-17	Clear Sky (Wow! Signal Coordinates)	Baseline Drift Scan	4	No
28-Jan-17	266/P (at Wow! Signal Coordinates)	Drift Scan	5	Yes
28-Jan-17	Sun	Baseline Drift Scan	2	Yes
28-Jan-17	Galactic Plane	Baseline Drift Scan	5	Yes
29-Jan-17	Clear Sky (Wow! Signal Coordinates)	Baseline Drift Scan	5	No
30-Jan-17	Clear Sky (Wow! Signal Coordinates)	Baseline Drift Scan	5	No
30-Jan-17	Clear Sky (Wow! Signal Coordinates)	Baseline Drift Scan	5	No
30-Jan-17	Clear Sky (Wow! Signal Coordinates)	Baseline Drift Scan	5	No
22-Feb-17	Comet P/2013 EW90	Baseline Drift Scan	15	Yes
23-Feb-17	Comet P/2016 J1-A	Baseline Drift Scan	16	Yes
24-Feb-17	Comet 237P/LINEAR	Baseline Drift Scan	20	Yes
Total Observations			200	

Table 1:

List of observations conducted from 27 November 2016 to 24 February 2017.

During all phases of this investigation, the 10-meter radio telescope was tested and calibrated *daily* to ensure accuracy. Furthermore, all data collected was handwritten and logged into the Center for Planetary Science Observation log, which was then typed and saved as a PDF file. As a reference for the reader, all altitude and azimuth noted hereafter are in relation to the Site-B Observatory, which is located in Wesley Chapel, FL and the coordinates for comets 266/P Christensen, P/2013 EW90 (Tenagra), P/2016 J1-A (PANSTARRS), and 237P/LINEAR were obtained from the JPL Small Bodies Database.

Baseline Data Collection of Radio Galaxy Cygnus

To establish a baseline for 1420 MHz, and to disqualify potential noise, the 10-meter radio telescope was directed toward Cygnus A during several observing days (Table 1). The galaxy Cygnus A, which is 263 megaparsecs away [5], is the strongest known celestial radio source, other than the Sun, in the sky. Cygnus A contains an active galactic nucleus. The source of this strong radio signal is a result of the dense region at the center of the galaxy, which has a much greater than normal luminosity of the electromagnetic spectrum [6]. This excess emission, which is thought to be a result of the accretion of matter by a supermassive black hole [6], can be observed at 1420 MHz. The Site-B 10-meter radio telescope was directed toward Cygnus A on five separate dates for a total of 24 observations (Table 1). The purpose of these observations were to determine the accuracy of the radio telescope's position toward known celestial coordinates, to acquire a baseline reading at 1420 MHz, and to collect data from Cygnus A in both spectral and continuum mode.

Cygnus A Profile in Spectral Mode

All observations of Cygnus A (Table 2) produced strong radio emissions at 1420 MHz. On average, the baseline signal as Cygnus A drifted into the lobe of the telescope increased 9.70 dB. (Figure 1). As Cygnus A drifted away from the lobe of the telescope, the signal decreased 16.4 dB. The observations of Cygnus A, therefore, concluded that the 10-meter radio telescope's azimuth and altitude indicators were optimally functional, the 10-meter radio telescope detected radio emissions at 1420 MHz, and a spectral baseline of neutral hydrogen from a known celestial source could be later compared with comet 266/P Christensen.

Right Ascension	20 ^h 00 ^m 01.49 ^s
Declination	+56° 27' 28.0"
Altitude	+56° 27' 28.0"
Azimuth	057° 58' 40.6"
Galactic Longitude	076° 11' 23.3"
Galactic Latitude	+05° 45' 19.6"

Table 2: Celestial Coordinates of Galaxy Cygnus A on 14 December 2016 at 1222 EST

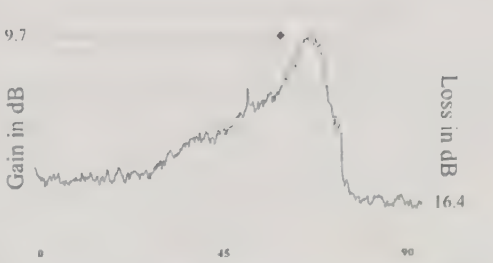


Figure 1: 1420 MHz Radio Emission from Galaxy Cygnus A on 14 December 2016 at 1222 EST

Cygnus A Profile in Continuum Mode

Observations of Cygnus A (Table 3) in continuum mode produced strong radio emissions at 1420 MHz. On average, the baseline signal as Cygnus A drifted into the lobe of the telescope increased 10.20 dB. (Figure 2). As Cygnus A drifted away from the lobe of the telescope, the signal decreased 9.11 dB. The observations of Cygnus A, therefore, concluded the 10-meter radio telescope’s azimuth and altitude indicators were optimally functional, the 10-meter radio telescope detected radio emissions at 1420 MHz, and a continuum baseline of neutral hydrogen from a known celestial source could be later compared with comet 266/P Christensen.

Right Ascension	20 ^h 00 ^m 03.66 ^s
Declination	+40° 46' 58.8"
Altitude	+71° 20' 25.2"
Azimuth	316° 22' 25.1"
Galactic Longitude	076° 11' 23.3"
Galactic Latitude	+05° 45' 19.6"

Table 3: Celestial Coordinates of Radio Galaxy Cygnus A on 10 January 2017 at 1416 EST



Figure 2: Radio Galaxy Cygnus A on 10 January 2017 at 1416 EST

Table 4: Drift Scan Celestial Coordinates for Galactic Plane Observations

	RA Start	Declination Start	RA End	Declination End
Scan A	17h58m03.77s	-18°58'54.7"	18h57m43.31s	-17°25'06.4"
Scan B	17h50m59.16s	-24°12'30.6"	18h55m24.84s	-24°44'39.3"
Scan C	17h48m37.55s	-27°49'59.5"	18h54m11.13s	-27°43'56.0"

Baseline Data Collection of the Galactic Plane

The Site-B 10-meter radio telescope was directed toward the Milky Way's Galactic Plane (Table 4) on six separate dates for a total of 30 observations (Figure 3). The Milky Way's Galactic Plane is the plane in which most of the galaxy's mass lies. The Galactic Plane is the most common known source of strong radio emissions in the electromagnetic spectrum, including at 1420 MHz [7]. Throughout this experiment the edge of the Galactic Plane, as viewed from an East to West azimuth, was 23° from the coordinates of the "Wow!" signal and the location of comet 266/P Christensen.

The purpose of these observations was to determine the accuracy of the radio telescope's position toward the sky, to conduct a baseline reading at 1420 MHz, and to locate and identify known/unknown celestial radio sources that could account for as the source of the 1977 "Wow!" signal. The acquisition times for these sets of observations were 40 minutes long, which provided sufficient time for the Galactic Plane to drift completely over the lobe of the telescope.

Galactic Plane Profile in Spectral Mode

Observations of the Galactic Plane in areas A, B, and C (Figures 4, 5, and 6) did not detect strong radio sources at 1420 MHz. The gradual increase of the baseline signal was due to hydrogen gas approaching radially (blueshifted).

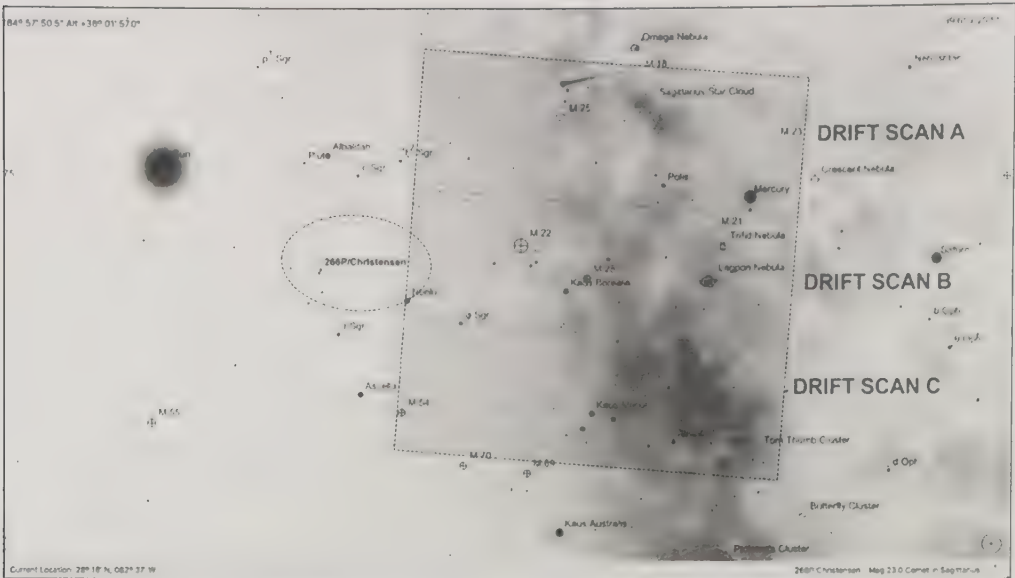


Figure 3: Location of scans and observations

Figure 4: Spectral Drift “A” Scan of Galactic Plan on 12 January 2017

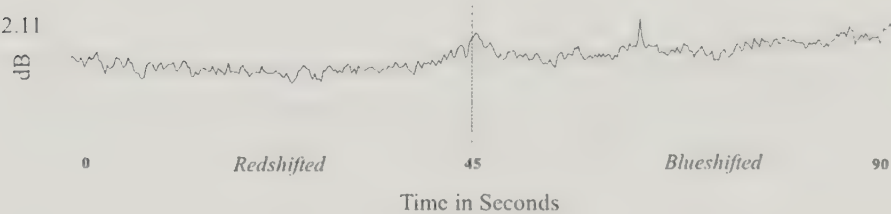


Figure 5: Spectral Drift “B” Scan of Galactic Plan on 19 January 2017



Figure 6: Spectral Drift “C” Scan of Galactic Plan on 20 January 2017



Galactic Plane Profile in Continuum Mode

Observations of the Galactic Plane in areas A, B and C detected a strong radio source at 1420 MHz (Figure 7). In an effort to acquire the Galactic Plane “edge on” as it drifted into and out of the lobe of the telescope, an acquisition time of 40 minutes was required. On average, the baseline signal as the Galactic Plane drifted into the lobe of the telescope increased 6.36 dB. (Figure 7). As the Galactic Plane drifted away from the lobe of the telescope, the signal decreased 11.45 dB.

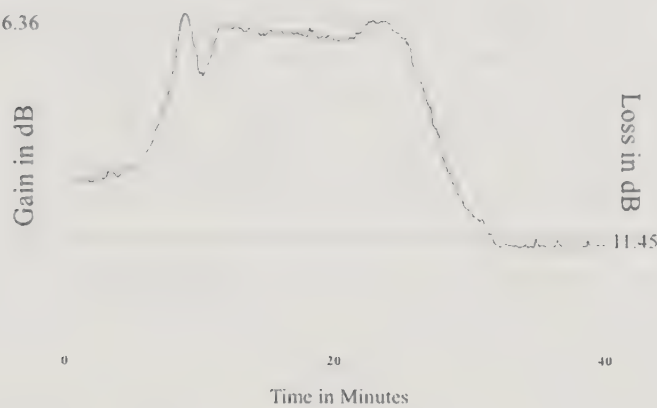


Figure 7: Drift Scan of Galactic Plane on 14 January 2017 at 1200 EST (Continuum Mode)

Baseline Data Collection of the Sun

From 27 November 2016 to 30 January 2017 33 observations of the Sun were completed (Table 5). The purpose of these observations were to obtain a baseline reading of neutral hydrogen and to confirm the accuracy of the telescope’s altitude and azimuth indicators *prior* to every observation of comet 266/P Christensen. All observations of the Sun detected a strong neutral hydrogen signal. The strength of the neutral hydrogen is represented as a single line moving up along the y and x axis (Figure 8) as the Sun drifted into the lobe of the telescope.

Right Ascension	17 ^h 17 ^m 06. ^s 55
Declination	25° 24' 29.2"
Altitude	58.4966610
Azimuth	72.18116
Galactic Longitude	60.1581111
Galactic Latitude	-0.57809

Table 5: Celestial Coordinates of the Sun
12 December 2016 at 1200 EST
(Continuum Mode)

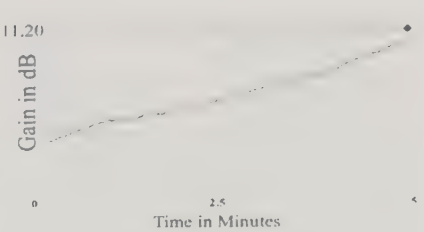
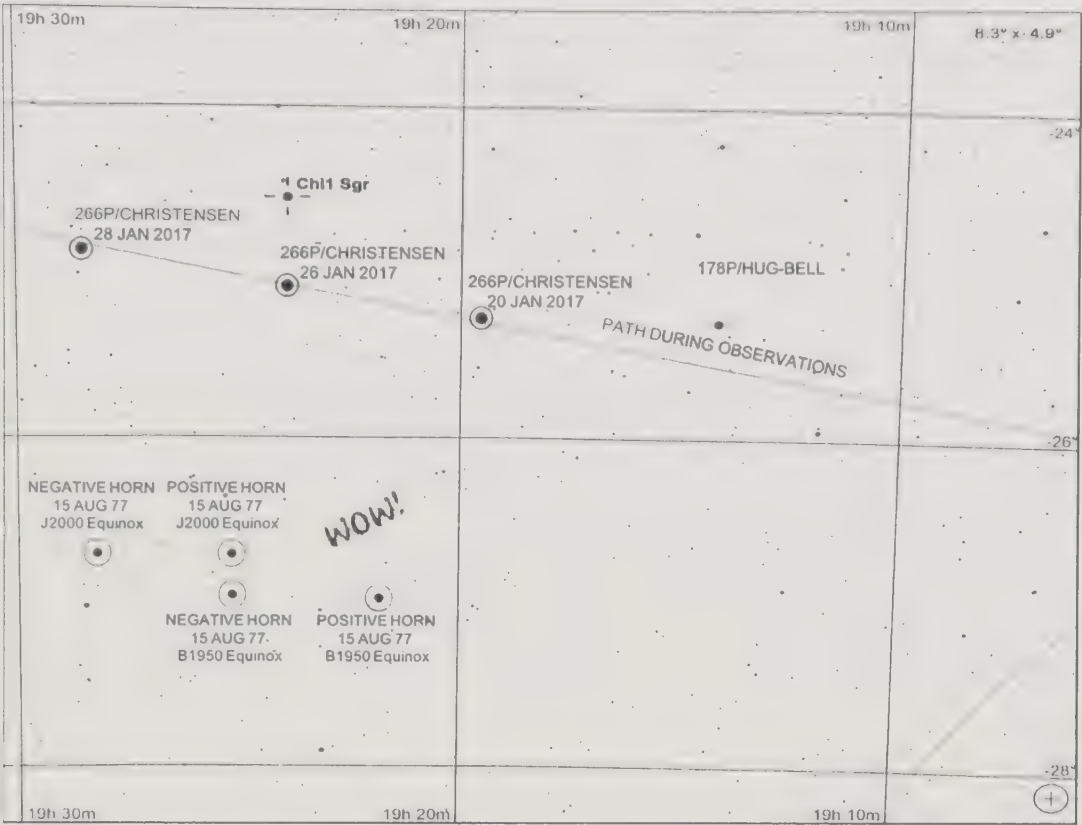


Figure 8: Drift Scan of the Sun on
12 December 2016 at 1200 EST
(Continuum Mode)

Observations of Comet 266/P Christensen

From 20 – 28 January 2017, the 10-meter radio telescope was directed at comet 266/P Christensen (Figure 9) as it transited near the coordinates of the “Wow!” signal. During all observations (Tables 6, 7 and 8) a radio signal with varying intensity at 1420.25 MHz was detected. On 20 January 2017, at 1100 EST, as comet 266/P Christensen drifted into the lobe of the telescope, the baseline signal increased 7.95 dB. As the comet drifted away from the lobe of the telescope, the signal decreased by 11.48 dB. (Figure 10). On 26 January 2017, at 1100 EST, as comet 266/P Christensen drifted into the lobe of the telescope, the baseline signal increased 8.32 dB. As the comet drifted away from the lobe of the telescope, the signal decreased 7.80 dB. (Figure 11). The final observation was conducted on 28 January 2017 at 1235 EST. As comet 266/P Christensen drifted into the lobe of the telescope, the baseline signal increased 9.97 dB. As the comet drifted away from the lobe of the telescope, the signal decreased 11.42 dB (Figure 12).

Figure 9: Date of Observations of Comet 266/P Christensen in relation to the coordinates of the Wow! signal in 1977



Repositioning of the Telescope during Observations of Comet 266/P Christensen

On 28 January 2017, at 1130 EST and 1200 EST, the 10-meter radio telescope was directed at comet 266/P Christensen. During both observations, a radio signal at 1420.25 MHz was detected. In an effort to dismiss the radio signal as emanating from comet 266/P Christensen, the radio telescope was repositioned “away from” and “back to” the comet. In the first experiment, the radio telescope’s azimuth was moved 1° (60 arcminutes) away from comet 266/P Christensen. As the telescope rotated away from the comet, the strength of the radio signal decreased 10.12 dB (Figure 13). Conversely, when the telescope rotated 1° (60 arcminutes) back to the comet, the radio signal increased 13.39 dB (Figure 14). The second set of experiments was centered on rotating the telescope’s altitude 1° (60 arcminutes) away from comet 266/P Christensen. When the telescope rotated away from the comet the signal decreased 9.3 dB. When the

telescope was redirected 1° (60 arcminutes) back to the comet the signal increased 8.7 dB (Figure 15).

Signal to Noise Ratio of Comet 266/P Christensen and the “Wow!” Signal

The maximum value of the “Wow!” Signal was 30 sigma (*i.e.*, 30 times the standard deviation of the data). The peak of the “Wow!” Signal, moreover, was about 30.76 sigma. This also means that the signal-to-noise ratio was about 30.76 at the peak.

By using the signal to noise ratio (*snr*) formula (Figure 16), where *pSignal* is the strongest signal strength we detected from 266/P Christensen (5.21 volts on 20 January 2017), *pNoise* is the background noise detected during the same observation of 266/P Christensen (3.55, 3.44, 3.14, 3.98), μ is the mean and σ is the standard deviation (sigma), we calculated that the *snr* for comet 266/P Christensen was 4.76 sigma. We infer, therefore, that the signal we detected during observations of 266/P Christensen was *not* background noise. We speculate that the strength of the original “Wow!” signal in 1977 (30 sigma) would have been accounted for the size of the Big Ear Radio Telescope (when compared to Site B’s 10-meter telescope) and/or the potential loss of mass from comet 266/P Christensen, which would have been considerably larger 40 years ago.

Measurements of Clear Sky in Sagittarius

From 28 - 30 January 2017, 24 clear sky observations in continuum mode were conducted. The purpose of these observations were two-fold: to determine if any radio signals at 1420 MHz could be detected *after* 266/P Christensen transited out of the area where the “Wow!” signal was detected; and to acquire a baseline of background noise near the coordinates of the “Wow!” signal. During these observations (Figures 17, 18, and 19), the baseline signal remained stable from 1.06 dB to 1.07 dB and no considerable radio emission at 1420 MHz, other than background and system noise, was detected.

Table 6: Celestial Coordinates of Comet 266/P Christensen on 20

Right Ascension	19 ^h 19 ^m 44.21 ^s
Declination	-25° 00' 23.1"
Altitude	+35° 24' 53.3"
Azimuth	166° 18' 20.1"
Galactic Longitude	012° 55' 08.0"
Galactic Latitude	-16° 46' 50.9"

Figure 16: Signal to Noise Ratio Formula

Table 7: Celestial Coordinates of Comet 266/P Christensen on 26

Right Ascension	19 ^h 25 ^m 54.97 ^s
Declination	-24° 48' 54.9"
Altitude	+36° 21' 25.8"
Azimuth	171° 03' 39.3"
Galactic Longitude	013° 39' 41.9"
Galactic Latitude	-18° 00' 14.6"

Table 8: Celestial Coordinates of Comet 266/P Christensen on 28 January 2017 at

Right Ascension	19 ^h 28 ^m 01.32 ^s
Declination	-24° 44' 51.4"
Altitude	+34° 24' 38.1"
Azimuth	199° 08' 19.8"
Galactic Longitude	013° 55' 59.2"
Galactic Latitude	-18° 25' 17.9"

Figure 10: Drift Scan of Comet 266/P Christensen on 20 January

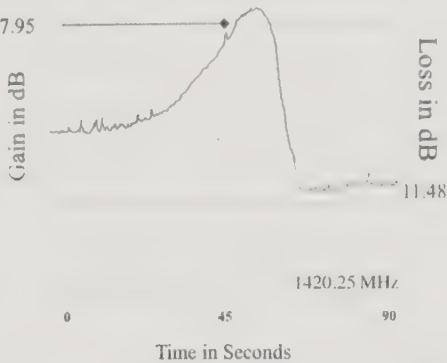


Figure 11: Drift Scan of Comet 266/P Christensen on 26 January 2017 at 1100 EST

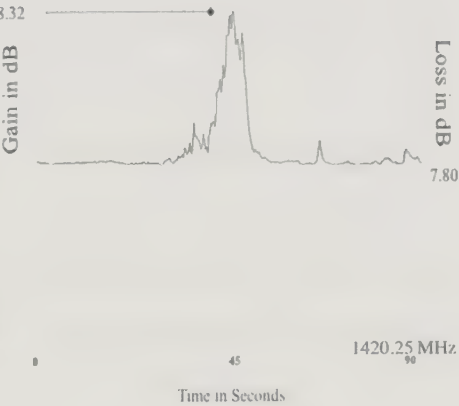
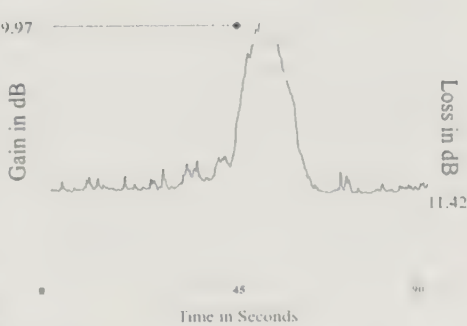


Figure 12: Drift Scan of Comet 266/P Christensen on 28 January



$$snr = \frac{pSignal}{pNoise} = \frac{\mu}{\sigma} \quad \text{whereas} \quad \mu = \frac{x1+x2...+Xn}{n} \quad \text{and} \quad \sigma = \sqrt{\frac{1}{n-1} \sum_{i=1}^n (x_i - \mu)^2}$$

$$\mu = \frac{3.55 + 3.44 + 3.14 + 5.21 + 3.98}{5} = 3.864$$

$$\sigma = \sqrt{\sum_{i=1}^n (x_i - \mu)^2} = 0.811$$

$$\frac{\mu}{\sigma} = \frac{3.864}{0.811} = 4.76$$

$$\sigma = \sqrt{\frac{1}{n-1} \sum_{i=1}^n (x_i - \mu)^2} = \sqrt{\sum_{i=1}^n (x_i - \mu)^2} = (3.55 - \mu)^2 + (3.44 - \mu)^2 + (3.14 - \mu)^2 + (5.21 - \mu)^2 + (3.98 - \mu)^2$$

Figure 17: Clear Sky Drift Scan on 28 January 2017 where comet 266/P Christensen was on 20 January 2017



Figure 18: Clear Sky Drift Scan on 29 January 2017 where comet 266/P Christensen was on 26 January 2017

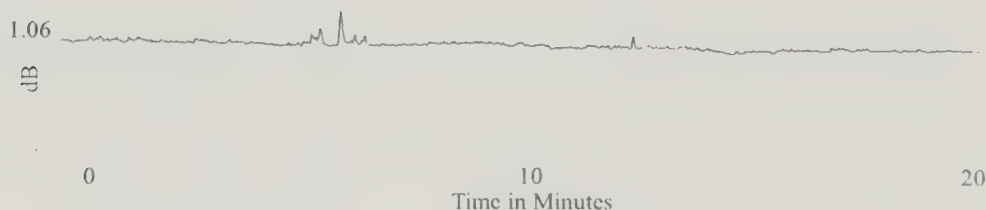
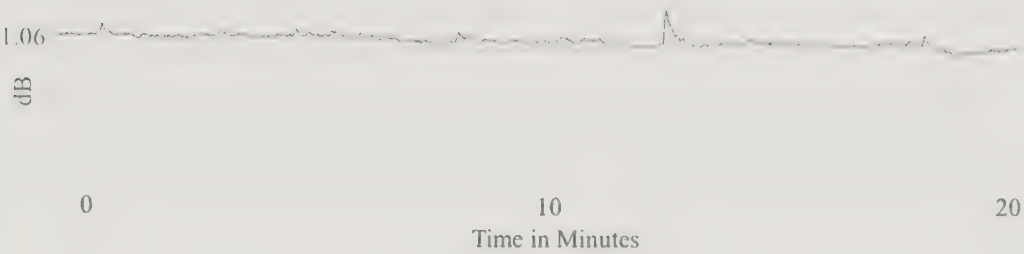


Figure 19: Clear Sky Drift Scan on 30 January 2017 where comet 266/P Christensen was on 28 January 2017



Observations of Three Random Comets

From 22 – 24 February 2017, the 10-meter radio telescope was directed at three random comets selected from the JPL Small Bodies Database. The comets selected were P/2013 EW90 (Tenagra), P/2016 J1-A (PANSTARRS), and 237P/LINEAR. The purpose of these observations was to determine if a comet other than 266/P Christensen emitted a radio signal at 1420 MHz. During observations, these comets were more than 10° from the Sun and more than 20° from the Galactic Plane.

On 22 February 2017, the 10-meter radio telescope made 15 observations of comet P/2013 EW90 (Tenagra) as it transited the constellation Aquarius. During these observations, a radio signal with varying intensity at 1420 MHz was detected. At 1100 EST, as comet P/2013 EW90 (Tenagra) drifted into the lobe of the telescope, the baseline signal increased 5.62 dB (Figure 209). As the comet drifted away from the lobe of the telescope, the signal decreased by 5.67 dB. All 15 observations of P/2013 EW90 (Tenagra) detected a radio signal at 1420 MHz.

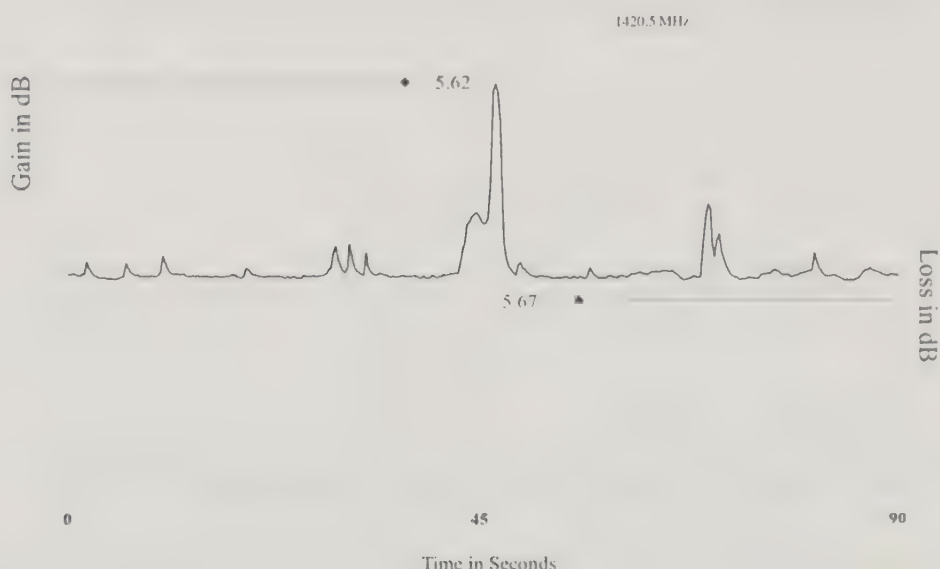


Figure 20:

Drift Scan of Comet P/2013 EW90 (Tenagra) on 22 February 2017 at 1100 EST

On 22 February 2017, the 10-meter radio telescope made 16 observations of comet P/2016 J1-A (PANSTARRS) as it transited the constellation Aquarius. During these observations, a radio signal with varying intensity at 1420 MHz was detected. At 1130 EST, as comet P/2016 J1-A (PANSTARRS) drifted into the lobe of the telescope, the baseline signal increased 5.64 dB (Figure 21). As the comet drifted away from the lobe of the telescope, the signal decreased by 5.22 dB. All 16 observations of P/2016 J1-A (PANSTARRS) detected a radio signal at 1420 MHz.

On 24 February 2017, the 10-meter radio telescope made 20 observations of comet 237P/LINEAR as it transited the constellation Aquarius. During these observations, a radio signal with varying intensity at 1420 MHz was detected. At 1230 EST, as comet 237P/LINEAR drifted into the lobe of the telescope, the baseline signal increased 5.40 dB (Figure 22). As the comet drifted away from the lobe of the telescope, the signal decreased by 5.63 dB. All 20 observations of 237P/LINEAR detected a radio signal at 1420 MHz.

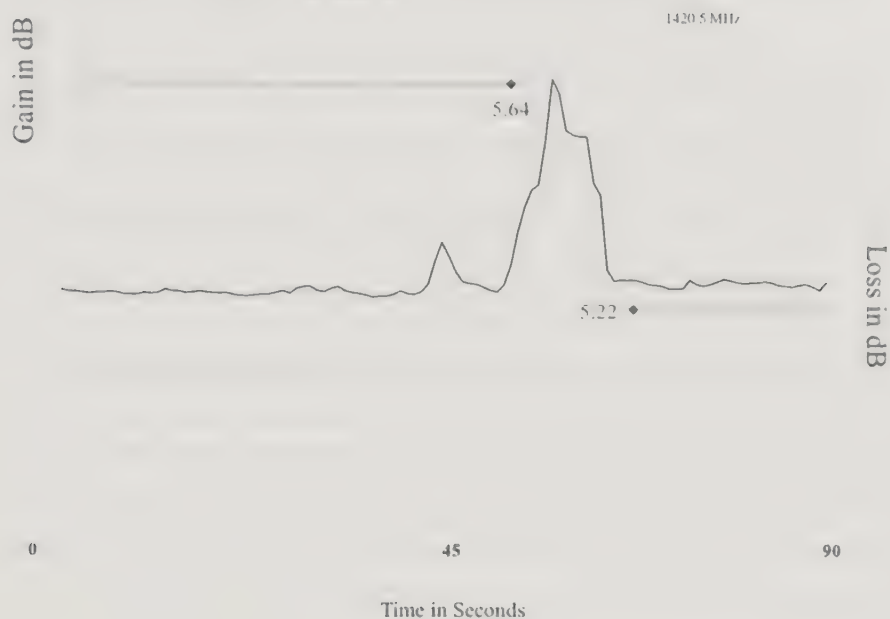


Figure 21:

Drift Scan of Comet P/2016 J1-A (PANSTARRS) on 23 February 2017 at 1130 EST

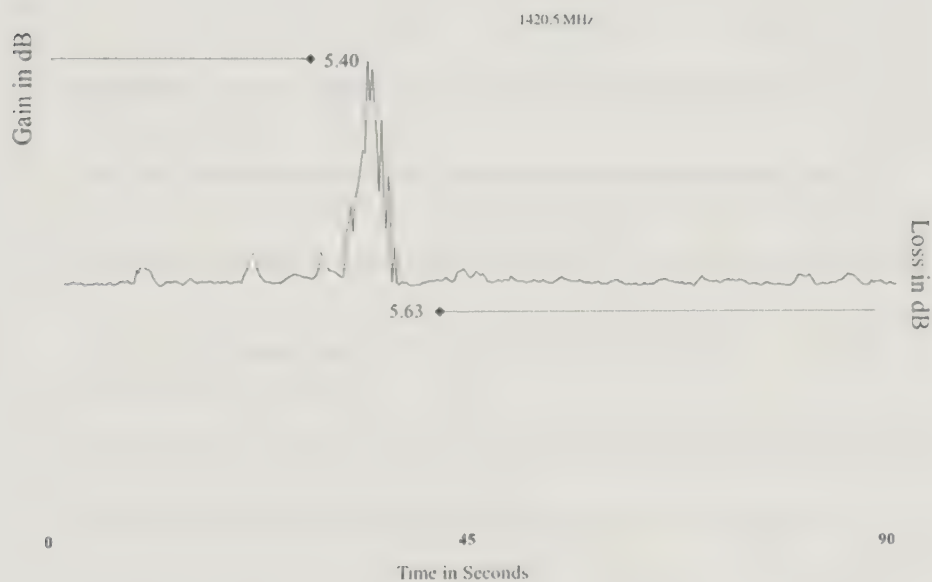


Figure 22:

Drift Scan of Comet 237P/LINEAR on 24 February 2017 at 1230 EST

Analysis and Interpretation of Data

Upon completion of the 200 observations, a comparison of the neutral hydrogen lines from Cygnus A, the Galactic Plane, the Sun, comet 266/P Christensen, and the clear sky were conducted. An analysis (Figure 23) of these spectra established a well-defined distinction between the signals acquired during this investigation. Radio celestial sources such as Cygnus A, for example, illustrate a strong increase and decrease of dB as the radio signal drifted into and of out the lobe of the telescope. When compared to the spectra from comet 266/P, there is a clear (but weaker) similarity between the spectra of the comet and Cygnus A. Spectra of the Galactic Plane, the Sun, and clear skies, however, presented no similarities when compared to the comet. We conclude, therefore, that the neutral hydrogen signal acquired during observations of 266/P Christensen were not from a known celestial source and, more importantly, were emitted by the comet.



Figure 23: A Comparison of Neutral Hydrogen Observations

Conclusions

In 2016, we proposed a hypothesis arguing that a comet and/or its hydrogen cloud was a strong candidate for the source of the “Wow!” signal. From 27 November 2016 to 24 February 2017, we conducted 200 observations in the radio spectrum to validate the hypothesis. This

investigation discovered that comets 266/P Christensen, P/2013 EW90 (Tenagra), P/2016 J1-A (PANSTARRS) and 237P/LINEAR emitted radio waves at 1420 MHz. Additionally, the data collected during this investigation demonstrated there is a well-defined distinction between radio signals emitting from known celestial sources and comets, including 266/P Christensen. After 25 observations of 266P Christensen, we are confident the radio telescope detected HI that outgassed from the comet.

We speculate that the strength of the original signal in 1977 would have been accounted for the size of the Big Ear Radio Telescope (when compared to Site B) and/or the potential loss of mass from comet 266/P Christensen, which would have been considerably larger 40 years ago. Additionally, while neutral hydrogen clouds have been observed around other comets (mostly from Lyman alpha spectra), determining the physical extent and density of the clouds around comets 266/P Christensen, P/2013 EW90 (Tenagra), P/2016 J1-A (PANSTARRS) and 237P/LINEAR was not the purpose of this investigation. In 2019, the Center for Planetary Science will conduct further observations of 266/P Christensen to measure the amplitude, strength and brightness of the comet's Lyman alpha spectra. In an effort to dismiss the source of the radio signal as emitting from 266/P Christensen, we repositioned the telescope away from the comet and conducting clear sky observations when the comet was not near the coordinates of the "Wow!" signal. During these clear sky observations, we detected no significant radio signal at 1420 MHz. This investigation, therefore, has concluded cometary spectra are observable at 1420 MHz and that the 1977 "Wow" Signal was natural phenomena from a Solar System body.

Bio

Antonio Paris is a Professor of Astronomy at St. Petersburg College, FL; the Chief Scientist at the Center for Planetary Science; and the Director of Planetarium and Space Programs at the Museum of Science and Industry in Tampa, FL. In 2016, in this Journal, he published *Hydrogen Clouds from Comets 266/P Christensen and P/2008 Y2 (Gibbs) are Candidates for the Source of the 1977 "Wow!" Signal* – the hypothesis that led to this investigation. He is a member of the American Astronomical Society and is currently conducting research on gamma-ray pulsars, neutron stars and black holes.

Acknowledgments

This investigation could not have been completed without the hard work and dedication from Dennis Farr, Chief Technician at the Center for Planetary Science; Ryan Robertson, an undergraduate planetary science student at American Public University; Jeffrey Lichtman and Carl Lyster from Radio Astronomy Supplies; and Edward Geiger, Consulting Telescope Engineer during this investigation.

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En Hedu'anna

Sethanne Howard

USNO, retired

Abstract

This is the story of the first scientist in human history; a women who was called the Shakespeare of the ancient world and who gave us the calendars used to date religious holidays.

Introduction

MANY PEOPLE, when asked to name an early scientist who is a woman, say Hypatia (Hy-pa-ti'-a). She lived in Alexandria, Egypt around 400 CE. Actually they are about 2700 years too late! Women have been active in science since the beginning of written history. So cast your thoughts backward in time to 4300 years ago – the time of Sumer (an ancient civilization in southern Mesopotamia – modern Iraq). Writing had not been around for very long (developed c. 3000 BCE).

En Hedu'anna was the chief astronomer priestess of the ancient city of Ur. She lived c. 2300 BCE. This is her story, the first scientist in ancient history whose name we know and writings we have. Note that she was not called a 'scientist'. That term did not come into general use until the mid-19th century. So who we call a scientist today was earlier known as an astronomer/mathematician, philosopher, or priestess. Those who were 'scientists' were also part of the religious structure. Religion was deeply embedded in the culture.

Science has been the business of women ever since the time of En Hedu'anna. Certainly, though, women (and men) were questioners and thinkers long before that. Most myths, religions, and history place the beginnings of agriculture, laws, civilization, mathematics, calendars, time keeping, and medicine into the hands of women. And the mythology is so very rich. The stories form our common wealth. But whether it was the Goddess of Wisdom or War or Love she was lost to the historical record yet kept strong in the dreams and myths of all peoples.

Ur and Sumer

Ur was situated south of Bagdad (in modern day Iraq), just north of where the Tigris and Euphrates rivers split from each other. The plains in southern Mesopotamia regularly flooded from the Euphrates and the Tigris rivers, which may have given rise to the Mesopotamian and biblical great flood stories. The word Mesopotamia means between the rivers (the rivers meaning the Euphrates and Tigris Rivers). Figure 1 illustrates several ancient cities in Mesopotamia.

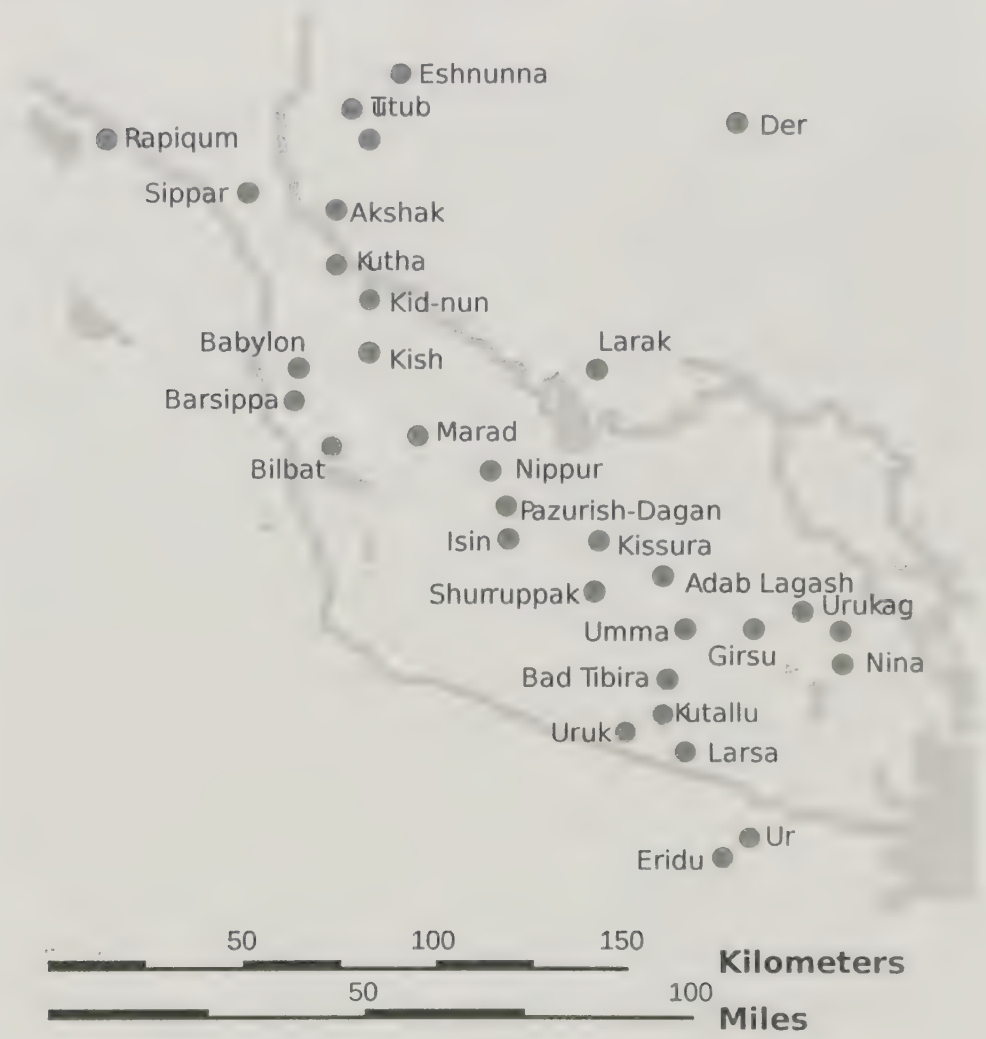


Figure 1 – several ancient cities in Mesopotamia. By the end of the third millennium 90% of the people lived in these city states. Based on Wikipedia content that has been reviewed, edited, and republished. Original image by Phirosiberia. Uploaded by Jan van der Crabben, published on 26 April 2012 under the following license: Creative Commons: Attribution-ShareAlike.

It might be said that history and science began in Sumer. Civilization developed in the lands around and between the Tigris and Euphrates rivers which flow southeast into the Persian Gulf.

Despite the nearby rivers canal based irrigation was vital to agriculture. The Tigris especially produced violent floods. The canals had to be cleared frequently. The layout and clearing of the canals required expert planning and engineering, while the division of the irrigated land, the water, and the crops required political control. The timing of what canal received water was critical to controlling the crop yield. One needed a “clock” to control the water release to an irrigation canal. They used a water clock. Figure 2 is an illustration of such a water clock.



Figure 2 – Persian water clock

A smooth bowl with a tiny hole in the bottom was placed in a platter of water. The bowl would slowly fill with water. When full it was time to change irrigation canals. Watching this was a critical job assigned to the most senior and responsible people. The bowl had to be monitored all day each day.

By 3000 BCE the Sumerians had formed *temple-communities*, in which a class of priest/priestess-bureaucrats controlled the political and economic life of the city. The common temple land was worked by all members of the community, while the remaining land was divided among

the citizens for their personal use at a rent of one third to one sixth of the crop. Priestesses and temple administrators, however, held rent-free lands. Rent (taxes) were paid in kind, usually cattle or sheep. For example, in one year the city of Elba in northern Palestine received over 36,000 sheep in taxes.

In its heyday Ur was a coastal city on the rim of the Euphrates and the Persian Gulf. As the most important port on the Persian Gulf it was the gateway to Mesopotamia. All imports via the sea with their accompanying wealth had to pass through Ur. An increase in trade between Sumerian cities and between Sumer and other, more distant regions led to the growth of a merchant class. According to one estimate, Ur was the largest city in the world from c. 2030 to 1980 BCE. The city covered over 1000 acres. Its population was approximately 65,000. About that time houses in the city were two-storied villas with 13 or 14 rooms with plastered interior walls. Today the coastline has shifted and the archaeological ruins are well inland (see Figure 3).



Figure 3 – archeological dig at Ur. The great ziggurat is visible in the distance.

Ur was one of the first real city states; as such it was one of the first, if not the first, centralized bureaucracy. Much of what we know about the people and culture of Mesopotamia comes from excavations in Ur. Excavation of the site, especially the royal tombs, brought out incredible wealth in gems, semi-precious stones, and precious metals. Artifacts from the tombs were displayed on a worldwide tour that included Washington DC.¹ A reconstructed and beautiful headdress of gold from the tomb of Lady Pun-Abi is shown in Figure 4. The thin, delicate gold work is amazing.



Figure 4 – reconstructed Sumerian headgear. By JMiall (Own work), CC BY-SA 3.0, <https://commons.wikimedia.org/w/index.php?curid=10648561>

The record keeping necessary for taxes led to the development of mathematics that included both a decimal notation and a base 60 system. Our sixty-second minute, sixty-minute hour, and 360 degree circle started with the Sumerians. The word ‘dozen’ means twelve, a fifth of 60. A dozen might be one of the earliest mathematical groupings because there are about twelve lunar cycles in a solar year. The Sumerians invented mathematical tables and used quadratic equations. The math and astronomy established by the Sumerians passed to the West through the Babylonians, the Persians, the Greeks, and later the Arabs.

Cuneiform

The Sumerian writing system is the oldest known. They used a reed stylus to make triangular (wedge) shaped marks on the wet clay tablets. These were very durable when baked. The tablets are not large; they are typically less than 25 centimeters on a side – small enough to fit into a pocket. Several thousand tablets have been found at Ur. The writing is called cuneiform, from the Latin *cuneus* meaning ‘wedge.’ Both sides of the tablet were used. Initially the Sumerians used writing primarily as a form of record keeping. The most common cuneiform tablets recorded transactions of daily life: tallies of cattle, sheep, and goats kept by herders for their owners, production figures, and lists for taxes, accounts, and contracts – the legalities we use today are not new. Figure 5 shows a clay tablet written earlier by En Hedu’anna in praise of the goddess Inanna.

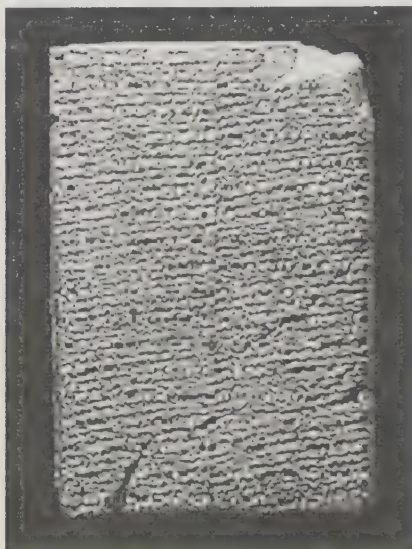


Figure 5 – The Exultation to Inanna Table, Nippur C 1750 BCE from the University of Pennsylvania Museum, Philadelphia (Neg. #S8-80401)

Cuneiform was difficult to learn. Temple schools were built to train the young people. A sub-category of cuneiform writing includes a large number of basic texts used to teach future generations of scribes. However it is important to note that these ancient schools were not for everyone. The temple schools were only for children of the privileged and wealthy. By 2500 BCE there were schools built for this purpose with female as well as male scribesⁱⁱ. Thus begins the idea that a learned person could read, write, and cipher. It was not until the late 19th century that this changed. By the

20th century a ‘learned’ person no longer could cipher. Math fell out of the standard training.

The leaders (recognizable by the syllable ‘en’ preceding each leader’s name) controlled the distribution of food and the irrigation systems; thus, they ruled the city. Each city had a temple associated with the local god. Let us call that local god ‘x’. Every citizen belonged to a temple, and the whole of a temple community was referred to as the ‘*people of god x*’. In the case of Ur ‘x’ was the goddess Innana. She was the goddess of love, beauty, sex, desire, fertility, war, combat, and political power.

En Hedü’anna

En Hedü’anna was the chief priestess of Ur. En Hedü’anna’s name in cuneiform is shown in Figure 6. Note that her name begins with ‘en’ meaning ruler. Her name is Sumerian meaning ‘she who is the chief ornament of heaven’.

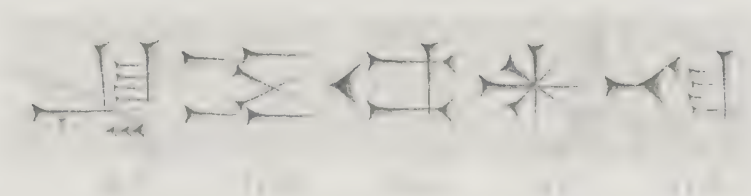


Figure 6 – Cuneiform for En Hedü’anna

Fortunately we have an abundance of Sumerian literature. There are tablets filled with poetry. Some small tables were letters that came encased in a slightly larger baked clay closed container, just as we use envelopes today. Poetry was used for other communications (*e.g.*, stories, religious works, laws, regulations, songs). What we would deem ‘literature’ developed from these early letters and poems.

The most famous Sumerian epic, and the one that has survived in the most nearly complete form, is the epic of Gilgamesh. The story of Gilgamesh, who actually was king of the city-state of Uruk in approximately 2700 BCE, is a moving story of the ruler’s deep sorrow at the death of his friend and of his consequent search for immortality. We do not know who wrote this great epic.

The first poems whose author we *do* know are the wonderful poems of En'Hedu'anna (c. 2300 BCE), the en-priestess of the city of Ur. Three long poems to the goddess Inanna, three poems to the god Nanna, and forty-two temple hymnsⁱⁱⁱ are found in translation today. I have seen the famous tablet she wrote honoring the Goddess Inanna. It is kept in the tablet vaults at the University Museum in Philadelphia. She was the only daughter of Sargon of Akkad (2334 – 2290 BCE) who established her in this leading position of the en-priestess. There are now excellent web sites describing her life and works.

Sargon of Akkad

Sargon was the world's first empire-builder, sending his troops as far as Egypt and Ethiopia. He established a unified empire of Sumer and Akkad and tried to end the hostilities among the city-states. Sargon's rule introduced a new level of political organization that was characterized by an even more clear-cut separation between religious authority and secular authority. To ensure his supremacy, Sargon created the first conscripted army, a development related to the need to mobilize large numbers of laborers for irrigation and flood-control works.

According to one cuneiform text he wrote that^{iv}:

“My mother was a high priestess, my father I knew not. The brothers of my father loved the hills. My city is Azupiranu, which is situated on the banks of the Euphrates. My high priestess mother conceived me, in secret she bore me. She set me in a basket of rushes, with bitumen she sealed my lid. She cast me into the river which rose over me. The river bore me up and carried me to Akki, the drawer of water. Akki, the drawer of water, took me as his son and reared me. Akki, the drawer of water, appointed me as his gardener. While I was a gardener, Ishtar granted me her love, and for four and ... years I exercised kingship.”

This is an early echo of the story of Moses (c. 1300 BCE, one thousand years later). Then other texts say^v:

“[Sargon] had neither rival nor equal. His splendor, over the lands it diffused. He crossed the sea in the east. In the eleventh year he conquered the western land to its farthest point. He brought it under one authority. He set up his statues there and ferried the west's booty

across on barges. He stationed his court officials at intervals of five double hours^{vi} and ruled in unity the tribes of the lands. He marched to Kazallu and turned Kazallu into a ruin heap, so that there was not even a perch for a bird left.”

The Sumerian king list went on from there. The third dynasty was established when the king Ur-Nammu came to power, ruling between c. 2047 BCE and 2030 BCE. During his rule, temples, including the great ziggurat in Ur, were built, and agriculture was improved through better irrigation. His code of laws, the *Code of Ur-Nammu* is one of the oldest such documents known, preceding the *Code of Hammurabi* by 300 years.

The Work of En Hedu'anna

With our first name, En Hedu'anna, the tradition of women in science and technology begins. We do not know her birth name. She was the chief astronomer-priestess and as such managed the great temple complex of her city of Ur. She controlled the extensive agricultural enterprise surrounding the temple as well those activities scheduled around the liturgical year. Although we do not have modern technical works from her (and we would not expect to have them), we know that she was a learned, diversely talented woman of power. And we have her poems. She used her creative talents in the written word, spreading her ideas and beliefs. Her poetry forms the first written form of a religious belief system. She codified and centralized religion, so that all might share the same belief system. Instead of each city having its own separate god, the cities shared a structured hegemony. She has been called the Shakespeare of the ancient world because her works were studied and recited for more than 500 years after her death^{vii}.

The historian Paul Kriwaczek writes^{viii},

“Her compositions, ..., remained models of petitionary prayer Through the Babylonians, they influenced and inspired the prayers and psalms of the Hebrew Bible and the Homeric hymns of Greece. Through them, ..., faint echoes can even be heard in the hymnody of the early Christian church.”

One of her hymns, number eight, contains an interesting clue. The poem has the following lines in it:

*The true woman who possesses exceeding wisdom,
She consults a tablet of lapis lazuli
She gives advice to all lands...
She measures off the heavens,
She places the measuring-cords on the earth*

Her poem describes the work of a scientist and leader. I think of her as wise (line 1). Lapis lazuli was very rare in Ur. Most was exported from beyond the northern mountains (modern Afghanistan). Only the ruling parties could afford such a tablet (line 2). Giving wide spread advice is the mark of a leader (line 3). To measure off the heavens is to engage in astronomy (line 4). To measure the Earth is surveying as well as astronomy (line 5). These are all technical subjects requiring great skill to accomplish.

There must have been some sort of calendar keeping (tracking the Moon) intrinsic to her position. It is from the work of these early astronomers that modern liturgical calendars developed. We date Easter, Passover, and Ramadan using work derived from the ancient Sumerians. They studied the sky to set up a calendar not just for religious events but also for tracking the due dates for taxes. I strongly suspect that tracking the dues dates for taxes was more important than tracking the due date for religious events.

They used the Moon as a timekeeper as it cycled through its phases. Each new Moon was announced by a group of priestesses called a *synod*. Hence the lunar month that cycles through the phases (new Moon to new Moon) is called a *synodic month*. The synodic month does not contain an exact number of days. Instead it is approximately 29.531 days. Using this lunar month they created a calendar based on the Moon. There are about 354 days in a lunar year (twelve cycles through the lunar phases). Because a lunar calendar is tied to the phases of the Moon, it does not synchronize with the seasons of the year. The seasons, on the other hand, cycle every 365.25 days as they move from summer to fall to winter to spring and back to summer. So the seasonal year was not in track with the lunar year. Tracking the two types of years meant that astronomy and math were necessary to the community.

Another of her poems describes her work

*“in the gi-par the priestesses’ rooms
that princely shrine of cosmic order
they track the passage of the moon.”*

The gi-par was where they lived and where they tracked the Moon to set the calendar. It was a holy place often accompanied by a sacred garden.

There exists an alabaster disk (also in the University Museum in Philadelphia) that shows her in a procession (see Figure 7). She appears in full religious regalia, the third person from the right on this restored alabaster disc 25.6 cm in diameter. En Hedu’anna is our first woman of power and scholarship whose name we know, and the last in a long line of unknown powerful women of the past who followed the stars and the cycles of the Moon. For the next 500 years a daughter of the king was en-priestess of Ur.

En hedu’anna was the first in the long line of scientists to give us the beginnings of science and mathematics.

This early Shakespeare of Sumer was a lady whose thoughts and writings lasted through millennia. She gave us so much, not the least of which were calendars, math, and prayers.



Figure 7 Alabaster disk showing En'Hedu'anna
Courtesy University Museum

Conclusion

It would be easy to say that En Hedu'anna was unique and toss her aside. But she was not. There were many such en-priestesses, each a powerful woman who controlled commerce and study. En Hedu'anna's daughter and granddaughter held that same position. Legend claims that Queen Semiramis is the inventor of canals and bridges over rivers and the first to build a tunnel under a river – the Euphrates – to found the city of Babylon. The legend is probably based on Sammeramet who acted as regent of Assyria from 810 – 805 BCE. There are also poets from this part of the world – Inib-sari (c. 1790 – 1745 BCE) and Eristi-Aya (c. 1790 – 1745 BCE) who lived in Akkadia. They were daughters of the king of Mari (in Syria), Zimri-Lin. He appointed his daughter, Kiru, mayor of a nearby town.

Around the time of En hedu'anna there were a few other early scientists (one happens to be male); however, they are more shrouded in myth than En hedu'anna. She stands out as one of our great scientists. She certainly was not a woman scientist. That implies that the single word 'scientist' (without the accompanying gender) means male. Women have shared the exciting world of science and technology with men from the very beginning of written history. So we drop the identifying gender unless we use it for both.

For more information on En'hedu'anna see the Web. The web site <http://4kyws.ua.edu> for students contains a little information about her and many others. The book *The Hidden Giants* (third edition) available from Amazon contains a lot of material on hundreds of scientists who happened to be women.

ⁱ <https://en.wikipedia.org/wiki/Ur>

ⁱⁱ Amat-Mamu was a female scribe during the time of Hammurabi.

ⁱⁱⁱ *Inanna, lady of largest heart*, Betty De Shong Meador, University of Texas Press, Austin, 2000

^{iv} Paul Kriwaczek, *Babylon*, St. Martin's Press, New York, 2012.

^v *ibid*

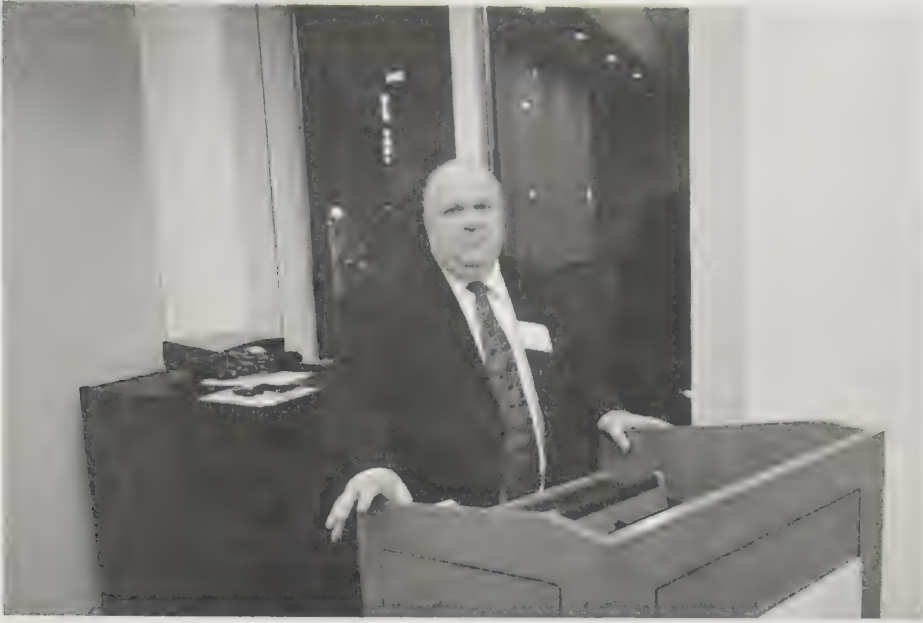
^{vi} A double hour was used during this time. The day was divided into two sections, each six hours long, thus making the day twelve hours in duration.

^{vii} Fryner-Kensky *In the Wake of the Goddesses*, NY, The Free Press, 1992

^{viii} Paul Kriwaczek, *Babylon*, St. Martin's Press, New York, 2012.

Bio

Dr. Sethanne Howard is an astrophysicist retired from the US Nautical Almanac Office at the US Naval Observatory. Her avocation is the history of women in science. Her website is 4kyws.ua.edu. The accompanying book is *The Hidden Giants* available through Amazon.



Remarks from the Outgoing President, Mike Coble

Dear Colleagues,

To our award winners and their special guests – congratulations! We are excited to welcome you into the Washington Academy of Sciences. I would like to thank our guest speaker for the banquet, Dr. Kate Dooley, for a wonderful talk on the research that she performs at the National Gallery of Art.

I would like to give a heartfelt thanks and acknowledgment to Trideum Biosciences. Trideum has made a generous donation to the Academy to cover the cost of the banquet for all our awardees and their guest. We appreciate this generosity which was also provided at last year's banquet.

It has been an honor to serve as the President of the Washington Academy of Sciences for the past year. I would like to especially thank all my friends and colleagues on the Board of Managers for their assistance and guidance throughout the year.

I would especially like to recognize our current VP of Administration, Terry Longstreth. Terry stepped into this pivotal role for the organization during a challenging time and has used his exceptional organizational skills to improve the operations of the Academy.

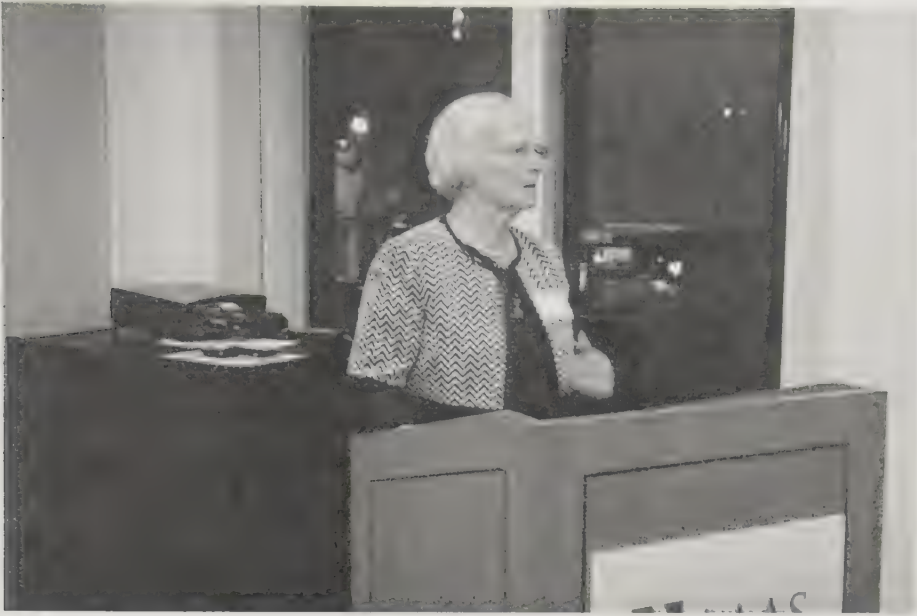
I would also like to acknowledge the great work that Paul Arveson has provided to the Academy over the last year. Last fall, Paul stepped up to

become the VP of the Junior Academy and has done a wonderful job connecting and mentoring future scientists in the D.C. region. Paul is always on the lookout for judges of science fairs, so I am sure he would love to talk to you if you are interested in helping!

Sethanne Howard continues to be not only a valuable resource for the history of our Academy, but an outstanding Editor for the *Journal of the Washington Academy of Sciences*. The Winter 2016 issue dedicated to the late Dr. Katherine Gebbie was just as spectacular as Katherine herself. Katherine was a fixture at our Annual Meeting and Awards Banquet and served behind the scenes for the Academy. She will be missed.

Finally, I would like to introduce the new President and members of the Board of Managers for the 2017-2018 term as confirmed from the election and the Committee of Tellers: Sue Cross will be our next President; Mina Izadjoo will be our next President-elect; Terry Longstreth will continue to serve as VP of Admin; Paul Arveson will continue to serve as the VP of the Junior Academy; Eugene Williams continues to serve as the VP of the Affiliated Societies; our new VP of Membership is Ram Sriram – we look forward to having you on the board next year. We will also have a new Secretary, Anna Maria Berea. John Kaufhold has done an outstanding job as our Secretary for the past few years, and we appreciate his service. Sethanne Howard will continue to serve as the Editor of the Journal, and Ron Hietala will continue to serve as our Treasurer. The members at large who will fill out the remainder of the Board will include: Fr. Frank Haig, Terrell Erickson, Michael Cohen, Meisam Izadjoo, Mary Sniekus, and Kathy Brady. I will serve as the Immediate Past-President. I hope to see you again soon!

Mike Coble



Remarks of Incoming President, Sue Cross

The Washington Academy of Sciences for over a century has represented science and scientific research with purity and integrity. The rostrum of past and present members is a list of outstanding and dedicated scientists. Our awardees this evening help us to continue the traditions of the academy. As awardees, you have received a one year membership to the Washington Academy of Sciences. We welcome you and hope you will work with us this year and for years to come.

I am sure I will be able to do this job for the next year, because I am surrounded by people who actually know what they are doing. They all have my admiration and respect. I would like to thank Mike Coble (our President for this past year) and Mina Izadjoo (our current President elect) for letting me be on their team.

I will have Terry, Ron, Meissam, Sethanne, and Peg to answer my questions and steer me in the right direction.

Some of our goals for the coming year include:

- 1 Doing a better job communicating with all our members.
- 2 Expand the academy's efforts to reach out to science students in our high schools and colleges.

- 3 To meet with representatives of our Affiliated Scientific Societies.
- 4 Expand our marketing skills and reach out to the biomedical fields.
- 5 Make sure we have a wonderful awards dinner next year for outstanding scientists.

From the Academy members to you as award recipients, we extend our congratulations. It is an honor to be part of this celebration.

Sue Cross

2017 Awardees



James Filliben

Applied Mathematics



Hamid Gharavi

Computer Science



Kalman Migler
Physical Sciences



Jeffrey Bullard
Engineering Sciences



Kevin McGrattan
Engineering



Guruprasad Madhavan
Krupsaw Award



Dan Lozier

Mathematics and Computer Science



James Liddle

Physical Sciences



Laurie Liddle

Special Award for Excellence in Scientific Leadership



Jonathan Hardis

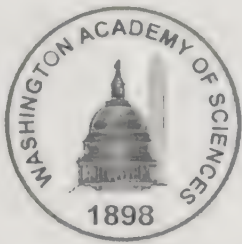
Special Award for Contribution in Science Policy



Terry Longstreth
Certificate of Appreciation



All the Awardees



Washington Academy of Sciences
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Please fill in the blanks and send your application to the address above. We will contact you as soon as your application has been reviewed by the Membership Committee. Thank you for your interest in the Washington Academy of Sciences.

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Home Address

Email

Phone

Cell Phone

preferred mailing address

Type of membership

____Business ____Home

____Regular ____Student

Schools of Higher Education attended	Degrees	Dates

Present Occupation or Professional Position _____

Please list memberships in scientific societies – include office held:

Instructions to Authors

1. Deadlines for quarterly submissions are:

Spring – February 1	Fall – August 1
Summer – May 1	Winter – November 1
2. Draft Manuscripts using a word processing program (such as MSWord), not PDF. We do not accept PDF manuscripts.
3. Papers should be 6,000 words or fewer. If there are 7 or more graphics, reduce the number of words by 500 for each graphic.
4. Include an abstract of 150-200 words.
5. Include a two to three sentence bio of the authors.
6. Graphics must be in graytone, and be easily resizable by the editors to fit the Journal's page size. Reference the graphic in the text.
7. Use endnotes or footnotes. The bibliography may be in a style considered standard for the discipline or professional field represented by the paper.
8. Submit papers as email attachments to the editor or to wasjournal@washacadsci.org.
9. Include the author's name, affiliation, and contact information – including postal address. Membership in an Academy-affiliated society may also be noted. It is not required.
10. Manuscripts are peer reviewed and become the property of the Washington Academy of Sciences.
11. There are no page charges.
12. Manuscripts can be accepted by any of the Board of Discipline Editors.

Washington Academy of Sciences Affiliated Institutions

National Institute for Standards & Technology (NIST)

Meadowlark Botanical Gardens

The John W. Kluge Center of the Library of Congress

Potomac Overlook Regional Park

Koshland Science Museum

American Registry of Pathology

Living Oceans Foundation

National Rural Electric Cooperative Association (NRECA)

Delegates to the Washington Academy of Sciences Representing Affiliated Scientific Societies

Acoustical Society of America, Washington Chapter	Shane Guon
American/International Association of Dental Research	J. Terrell Hoffeld
American Association of Physics Teachers, Chesapeake Section	Carl Mungan.
American Astronomical Society	Sethanne Howard
American Fisheries Society	Vacant
American Institute of Aeronautics and Astronautics	Vacant
American Institute of Mining, Metallurgy & Exploration	James B. Hedrick
American Meteorological Society	Vacant
American Nuclear Society	Vacant
American Phytopathological Society	Mahfuz Rahman
American Society for Cybernetics	Stuart Umpleby
American Society for Microbiology	Vacant
American Society of Civil Engineers	Vacant
American Society of Mechanical Engineers	Kaykham Sysounthorn
American Society of Plant Physiology	Mark Holland
American Society of Plant Biologists, Mid-Atlantic	Kimberly Gallagher
Anthropological Society of Washington	Vacant
ASM International	Toni Marechaux
Association for Women in Science	Leslie Jimison Hamilton
Association for Computing Machinery	Shahnaz Kamberi
Association for Science, Technology, and Innovation	F. Douglas Witherspoon
Association of Information Technology Professionals	Vacant
Biological Society of Washington	Vacant
Botanical Society of Washington	Karen Reddon
Capital Area Food Protection Association	Vacant
Chemical Society of Washington	Alan Anderson
District of Columbia Institute of Chemists	Vacant
District of Columbia Psychology Association	Vacant
Eastern Sociological Society	Vacant
Electrochemical Society	Robert Kelly
Entomological Society of Washington	Allen Norrbom
Geological Society of Washington	Jeff Plescia
Historical Society of Washington DC	Jurate Landwehr
Human Factors and Ergonomics Society	Julie B. Koczela Gerald Krueger

(continued on next page)

Delegates to the Washington Academy of Sciences Representing Affiliated Scientific Societies

(continued from previous page)

Institute of Electrical and Electronics Engineers, Washington Section	Richard Hill
Institute of Food Technologies, Washington DC Section	Taylor Wallace
Institute of Industrial Engineers, National Capital Chapter	Neal F. Schmeidler
International Association for Dental Research, American Section	Christopher Fox
International Society for the Systems Sciences	Vacant
International Society of Automation, Baltimore Washington Section	Richard Sommerfield
Instrument Society of America	Hank Hegner
Marine Technology Society	Jake Sobin
Maryland Native Plant Society	Vacant
Mathematical Association of America, Maryland-District of Columbia-Virginia Section	John Hamman
Medical Society of the District of Columbia	Julian Craig
National Capital Area Skeptics	Vacant
National Capital Astronomers	Jay H. Miller
National Geographic Society	Vacant
Optical Society of America, National Capital Section	Jim Heaney
Pest Science Society of America	Vacant
Philosophical Society of Washington	Larry S. Millstein
Society for Experimental Biology and Medicine	Vacant
Society of American Foresters, National Capital Society	Marilyn Buford
Society of American Military Engineers, Washington DC Post	Vacant
Society of Manufacturing Engineers, Washington DC Chapter	Vacant
Society of Mining, Metallurgy, and Exploration, Inc., Washington DC Section	E. Lee Bray
Soil and Water Conservation Society, National Capital Chapter	Erika Larsen
Technology Transfer Society, Washington Area Chapter	Richard Leshuk
Virginia Native Plant Society, Potowmack Chapter	Alan Ford
Washington DC Chapter of the Institute for Operations Research and the Management Sciences (WINFORMS)	Meagan Pitluck-Schmitt
Washington Evolutionary Systems Society	Vacant
Washington History of Science Club	Albert G. Gluckman
Washington Paint Technology Group	Vacant
Washington Society of Engineers	Alvin Reiner
Washington Society for the History of Medicine	Alain Touwaide
Washington Statistical Society	Michael P. Cohen
World Future Society, National Capital Region Chapter	Jim Honig

Washington Academy of Sciences

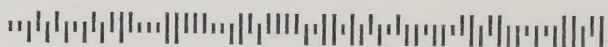
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